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The role of academic publishers in shaping the development of Web 2.0 services for scholarly communications

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Abstract

We present findings from two case studies of how scholarly communications service providers are responding to the opportunities and challenges of Web 2.0 to innovate their service offerings. We explore the experiences of two academic publishers as they have attempted to appropriate and innovate around Web 2.0 ideas and services. Our findings highlight the need to take seriously the role of publishers in the move towards a vision of more rapid and open scholarly communication and to understand the factors that shape their role as intermediaries in the innovation pathways that may be needed to achieve it.

Keywords: scholarly communications, Web 2.0, open science, e-Science, open access, innovation

Introduction

In the last 10 years, a rapidly expanding series of innovations in the technical tools, standards and practices collectively known as Web 2.0 would appear to offer the possibility of new forms of scholarly communications central to the realisation of the vision of reduced time to discovery and greater robustness of the research process (Arms and Larsen 2007; Hey, Tansley and Tolle 2009; Hannay, 2009; Goble et al., 2011). Proponents of 'Open Science' have seized upon the technical possibilities offered by Web 2.0 for fundamentally changing scholarly practices and communications (Neylon and Wu, 2009; Waldrop, 2008). However, our parallel study of attitudes towards new forms of scholarly communications (Procter et al., 2010a) has shown that majority of the scholarly community is unwilling to embrace these innovations. While some general purpose Web 2.0 tools and services have been adopted, where there is a need for more specialised tools these will have to be developed, incorporated into the institutions of scholarship, and new practices recognised and valued by individuals and the scholarly community. Our interest is in how this work is done, and who does it.

While we recognise explicitly that there are many exciting and interesting uses of Web 2.0 in other aspects of scholarly communication (Procter et al., 2010b), many of the possibilities of Web 2.0 concern the ability of individual scholars, research groups and institutions to publish, annotate, review and discover and make links between formal research outputs. New tools and practices that facilitate this would seem to challenge the role of established academic publishers, already heavily criticised for obstructing the move to Open Access, and which continue to provoke academic ire, as in the case of the Elsevier boycott of 2012¹. However, despite suggestions that academic publishers are somehow becoming irrelevant in the age of Web 2.0 and defending a business model that is out-dated and exploitative, we suggest that publishers may play an on-going role as innovation intermediaries (Stewart and Hyysalo, 2008; Howells, 2006) through their access to a unique set of resources to shape innovation and use, providing the scholarly community with opportunities to use and learn about Web 2.0. A recent survey of UK scholars suggests that most have little time or motivation to adopt and provide input to novel Web 2.0 services, despite recognising the potential, and enthusiastically embracing services such as Google Scholar (Procter et al., 2010a).

Technology-based experiments and deployments have been emerging from all parts of the research infrastructure: publishers, libraries, research labs, scholarly IT development

¹ 'The Cost of Knowledge' <http://thecostofknowledge.com/>

agencies, universities, funding bodies, scholarly societies, and from start-ups emerging from the world of research, as well as external players. None of these players in the world of scholarly communication stand out as being more motivated or better able to drive significant experimental innovation that actually gets in front of scholars in their everyday work. Academic publishers have incentives and can develop the expertise to develop and deploy a range of new tools and services and bring them to the scholarly community. Rather than offering one-off services, academic publishers are able to experiment over the longer term, integrating innovations with traditional services that remain in demand. However, success has been rather limited to date, and despite their position as 'obligatory points of passage' (Latour 1987) with privileged platforms to promote (or resist) change, any individual publisher will struggle to drive structural change in scholarly communication practices in a competitive environment where researchers expect common standards and services to link all their bodies of knowledge, whatever the source.

In research sponsored by the Research Information Network², we studied the adoption of Web 2.0 and its implications for scholarly communications for scholars and for others, including publishers. In a previous paper (Procter et al., 2010a), we reported on findings of researchers' use of Web 2.0. In this paper, as a complement, we present findings from two case studies of providers of Web 2.0 services for scholars, illustrating and comparing the efforts of two contrasting academic publishers, through the conceptual lens of the 'social shaping of technology' (MacKenzie and Wajcman 1985). We explore how these publishers have tried to build a bridge between scholarly communications technologies and practices by putting experimental services in front of scholars as they access articles online. The research questions that we sought to answer were: how are scholarly publishers seeking to maintain or reinvent their role in scholarly communications; and how are they going about identifying and creating new ways to deliver value? We find that while they largely failed in early attempts to create a scholarly versions of Web 2.0 applications, publishers are putting in place some key parts of the technical infrastructure that may eventually knit the scholarly article more closely into a network of other resources, and are playing a key role in animating debates and discussions.

This paper is not intended to provide a representative overview of the activities of all academic publishers, but a more in-depth investigation of the experiences of two prominent publishers as they attempt to appropriate and innovate around Web 2.0 ideas and services. Though their positions are distinctive, we argue that their experiences are similar to those faced by many publishers. We are not attempting a critical examination of these publishers' stance on 'Open Access'. Our findings highlight the need to take seriously the role of academic publishers in the move towards a vision of more rapid and open scholarly communications, and to understand the factors that shape their role as intermediaries in the innovation pathways that may be needed to achieve it.

Web 2.0, Scholarly Communication and Academic Publishing

Our evidence is drawn from a study investigating the extent to which Web 2.0 resources represent a new and useful means of communicating, sharing and disseminating research ideas and outputs for researchers across different disciplines, and exploring the implications for the future of scholarly communications (Procter et al., 2010b). Web 2.0 is a term that originated as a business concept for Internet companies after the 'dot.com-boom' and is starting to be developed into a set of general principles that contrast with the 'Web 1.0' of static websites, and closed data-base driven eCommerce and information services (such as library catalogues) that were given Web interfaces in the 1990s. However, it is often more easily identified by the forms of particular services, publishing formats or user practices that bridge and enhance these closed and managed information services. We started with a catch-all definition that brings together four of the ideas typically associated with Web 2.0,

"Web 2.0 encompasses a variety of different meanings that include an increased emphasis on user-generated content, data and content sharing and collaborative

² Funded by the Research Information Network. The full report is available at www.rin.ac.uk/communicating-and-disseminating-research/use-and-relevance-web-20-researchers

effort, together with the use of various kinds of social software³, new ways of interacting with web-based applications, and the use of the web as a platform for generating, re-purposing and consuming content.' (Anderson, 2007)

We have chosen to use this approach to Web 2.0 in a way that does not just simply refer to the configuration of the technologies, but to the changing practices of communication and production of information by individuals and groups (O'Reilly, 2007). Indeed, Web 2.0 can best be characterised as the coupling of particular technologies and social practices, where there is a co-evolution of technologies, services, and practices, mediated by a range of stakeholders and groups, and where existing practices and use of communications technologies by scholars acts both as an opportunity and a barrier: an opportunity to introduce interfaces and functionality and services characteristic of Web 2.0.

Web 2.0-based innovation has been characterised by a huge number of experimental services and tools, often in 'perpetual beta' (Morris, 2006), that live or die on whether they are taken up by end-users. These stand in contrast to the more specialised information services that are purchased by high education and research institutions and provided as packaged solutions. Organisations that make up and intermediate the infrastructures of scholarly communications, such as publishers, libraries, professional associations and conference organisers, have spent the last 10 years attempting to incorporate the functions that these technologies promise into their own activities and business offerings. The diverse aspects of Web 2.0 and the hitherto lack of established standards and practices has favoured an experimental approach, which balances possibilities of 'open scholarship' with the often conservative practices of scholars and the limitations of existing formal scholarly information practices (Rowlands, 2004; Harley et al., 2010). These organisations have also had to meet the challenges of new intermediaries outside of the traditional world of scholarly communications, be it major players such as Google, researcher-led innovations, or commercial start-ups.

Traditionally, one of the key elements in the process of scholarly communication is the publication of peer-reviewed research in journals. Peer-reviewed publication is not only central to scholarship, but also the core currency in career and reputation building (Arms and Larsen, 2007; Harley et al., 2010). The mediators of this process, the journals, and their networks of editors and reviewers, are key actors in this process, providing not only practical resources, but also legitimacy, quality control and branding. Journal publishing is a diverse industry, involving scholarly societies, University Presses, large-scale publishing houses, such as Springer and Elsevier, medium sized and small independent publishers, publishing branded and 'white label' journals. In the past, a journal may have served a defined scholarly community, providing a publisher with a captive market. However contemporary scholars publish and draw on research papers from many journals, and new interdisciplinary development constantly challenges the boundaries of research disciplines, making 21st Century scholarly publishing a very different business to what it was 20 years ago.

Unfortunately, the majority of studies on scholarly publishing focus on the users: the academics, libraries, and systemic costs to 'Science' as a system (e.g. Tenopir & King 2000; Houghton et al., 2009; Björk, 2007). There is precious little literature on the business of academic publishers (Lorimer et al., 2011; King, 1981;), let alone on innovation practices of publishers as teams of people with ideas, business goals, and (limited) resources, as they react to the pressures of their user/suppliers and the opportunities of new technology (Perciali and Aaron, 2009). The academic publishing market has been through a period of considerable change in the last 20 years. First, there has been the shift to online publishing, requiring the investment and learning required not only to provide online access to journals, but also to computerise the entire publishing process, digitise archives, and provide new information tools to subscribers. For many publishing companies, it has not been a matter of developing technology, but buying software and services from specialised suppliers as it becomes available, adopting open source packages, and trying to develop and improve information standards. Second, the relationship with the primary customers, academic

³ See, for example, a 2004 blog post by Christopher Allen frequently cited as an early discussion, who credits Clay Shirky with the 'loose' term, social software: Tracing the Evolution of Social Software, http://www.lifewithalacrity.com/2004/10/tracing_the_evo.html

libraries, has been revolutionised, shifting from subscriptions to individual journals, to bulk subscriptions for entire portfolios of journals provided only online. This has not only put enormous financial pressure on libraries, but also on small publishers unable to benefit from economies of scale. Third, the financial pressure on libraries and technical ease of online publishing awoke the Open Access movement: why should scholars and their funders pay to access electronic copies of papers they had written, edited, reviewed, and could make available on a personal or University website, or disciplinary repository (Tenopir and King, 1997; Johnson, 2000; Rowlands, 2004; Houghton et al., 2009)? It has taken over ten years to make open access publishing mainstream, involving changes in funding for publishing, individual publishing practice, and adoption of partial open access by mainstream publishers, such as Springer (who bought early-innovator BioMed Central in 2008), and it still remains a dominant issue in scholarly communications.

This environment, along with questions raised about other aspects of scholarly publishing practices such as peer-review (Smith, 2006), which a full 26% of our survey respondents expect to become increasingly unsustainable within the next five years (Procter et al., 2010b), and the 'tyranny' of impact driven publishing (Alberts et al., 2008) has been interpreted by some as a major factor in a 'crisis' in academic publishing. Others, such as the two organisations profiled in this paper, see this as an opportunity for innovation (Perciali and Aaron, 2008). For publishers to survive, publisher brands have to be strengthened, and the quality and breadth of their services improved, justifying their costs and value to scholars and the science industry. Failure of entrenched players to respond to the demands of researchers and the potentialities of new technology has also created opportunities for new entrants.

Conceptualising the socio-technological Innovation Processes

Web 2.0 undoubtedly characterises a period of experimentation in the role that information and communication technologies (ICTs) can play in a reshaped model of scholarly communication. In exploring these case studies, and the elements of innovation practice, we follow a Social Shaping of Technology (SST) approach (MacKenzie and Wajcman 1985; Williams and Edge, 1996). SST characterises innovation as essentially socio-technical, involving a seamless interplay between 'technical' and 'social' factors. Choices between different options available at every stage of technology development, implementation and use are shaped by the interactions between diverse actors with differing commitments, knowledges and perceived interests. Web 2.0 is thus not a given: it is created by people investing, experimenting and creating ideas: a finite number of small teams do this work, influenced by access to resources and a host of other constraints, and driven by visions of the potential of the technology. Their inventive work only comes to fruition as innovations that will benefit scholarly communities, if the scholars actually change their practices and adopt these technologies. Studies of ICT innovation (Sørensen, 1996; Williams et al., 2005) show that this involves generally lengthy processes of 'social learning': experimentation, interaction with potential users, failures, reinvention, and in-depth work with both technology and people to understand and shape technologies and practices. These processes are situated in domains of practice and existing social relations, and inspired by aspirations to change these and exploit possibilities of new technology. The emerging technological frames (Bijker 1995) of reference are not simply congealed from the hype of the techno-enthusiasts, but must be grounded in the pre-existing context and practices of stakeholders (Hyysalo, 2006), in this case, the practices of scholarly publishing. The common frame of reference for the organisation of scholarly communication has been under enormous strain in recent years and, while there may be some broad agreement on the potential of Web 2.0 to facilitate scholarly communication, there is clear disagreement about how this goal will be reached, and the role that existing entrenched stakeholders will end up playing.

Alongside the visionaries, investors and developers there is the vast mass of ordinary scholars, which this innovative activity is apparently designed to serve and whose interests and resources one would hope will eventually play a decisive role in shaping innovation pathways. This demands that the analysis focuses not only on powerful stakeholders, but on the detailed biographies of development and design, and on the evolving practices of users, and the interactions between the two. However, even this approach fails to capture the range of different types of actor involved in development processes and in the field of use. It is also important to identify various intermediaries that may play a key role in both stimulating and

gatekeeping innovation processes. The innovation literature highlights the potential contribution of various 'innovation intermediaries' (Howells, 2006) – actors that are situated 'between' the end-users and the producers of technologies and other stakeholders (in this case, scholars, the institutions of scholarship, and providers of Web 2.0 technologies and services). Intermediaries configure technical systems, broker knowledge transfer and stimulate debate, and create facilitating spaces where users can experiment with new technologies in familiar settings (Stewart and Hyysalo, 2008). In this case, the concept of intermediaries helps us to examine the intermediating activities of publishers and to draw conclusions about how successful they have been in playing this role.

Methodology

Our research design deployed a three-part methodology grounded in the Social Shaping/Social Learning approach (MacKenzie and Wajcman, 1985; Sørensen, 1996; Williams et al., 2005) that aimed not only capture current patterns of adoption, but also identify attitudes, problems, needs and aspirations of researchers, and how publishers are responding to the opportunities and challenges of Web 2.0.

We used an on-line survey to gather basic demographic data (age, gender, position and discipline), to document researchers' dissemination practices, to measure the extent of their research collaborations and uses of Web 2.0 resources, and to determine their attitudes towards new technology. This was complemented by 50 interviews with selected survey respondents. To investigate how publishers are exploring the possibilities offered by Web 2.0, we conducted case studies of five scholarly communications service providers. In each case study, we interviewed several key staff involved in Web 2.0-based service innovations and users of these services identified from survey responses. Interviews followed a semi-structured format, adapted to the particular activities of each organisation and individual. The questions were driven by the agenda of Social Shaping/Social learning, exploring the 'practice-bound' visions (Hyysalo, 2006) and probing the motivations driving Web 2.0 development activities, the organisational interests and constraints, representations of potential users, and interactions with stakeholders and end-users. The interviews were also informed and animated with reference to articles and blog posts published by the interviewees and their organisations. The interviews were recorded and transcribed for subsequent analysis. This mass of rich data was then analysed using a broadly 'grounded-theory approach' (Glaser and Strauss 1967), inductively identifying and iteratively developing themes as they emerge through reading and re-reading the data.

The two years between conducting the original interviews and the time to publish the paper is a relatively long time in the evolution of a topic such as Web 2.0. We took advantage of this interval period to re-establish contact with the original key informants of the case studies, along with an examination of the services and content available on the publishers' sites. This adds an important longitudinal dimension to the telling of the case studies, showing the change or lack of change in the development and use of the Web 2.0 services.

In this paper, we focus on two case studies of two leading publishers of conventional peer-reviewed research papers that come from opposite sides of the publishing industry, though they publish in similar fields: Nature Publishing Group (NPG) and Public Library of Science (PLOS)⁴.

NPG, with its flagship journal, *Nature*, founded 140 years ago, is one of the oldest scholarly publishers and has perhaps the strongest brand in academic publishing. It is a medium size, and very successful, for-profit business and operates with professional editors. In recent years it has invested considerably in innovation, including Web 2.0, creating Nature.com, Nature Blogs, and various data linking systems and as is seen as a leading player in the field. However, several of the NPG team subsequently left the company to set up a sister company within Macmillan to exploit data mining and software for science, beyond the confines of the NPG.

⁴ Although these publishers would define themselves as science publishers, our RIN study used the more general term scholarly publishers, and addressed all kinds of scholars, rather than just scientists.

For this case study we interviewed 5 members of the web development team, led by Timo Hannay, the team director. He is responsible for the strategic direction of the Nature.com platform, and for the more experimental services that may get incorporated into Nature.com. He had been with NPG for over ten years, running the Web development team, and taking on current responsibilities 5 years ago. He reports directly to the Managing Director of NPG. The other respondents develop and run the service, and joined in the last 3-4 years. Two are former research scientists, recruited for their experience of setting up Web 2.0 services outside, one is a 'new media' developer recruited from the BBC and the other a computer scientist specialising in Text Mining.

PLoS was a start-up 12 years ago, an experiment in open access publishing created by leading researchers in the US in an attempt to shake up the traditional forms of publishing. It is a non-profit organisation that publishes a range of leading journals. It is constantly experimenting with new ideas, such as continual publishing in PLoS One, and article level metrics. For this case study we interviewed the managing editor, Peter Binfield, the head of marketing and head of technology. The managing editor has 15 years experience in academic publishing and has overall responsibility for both the local and outsourced development teams. The head of marketing has 10 years experience in editing and marketing in academic publishing. Her role is to promote the journal and individual articles to the media. The head of technology, an open source enthusiast, leads the development team. The follow up interview was conducted with the new head of Products and Publications.

Every individual mentioned spoke both for the company and according to their own ideas and vision, which together contribute the direction and ideas of the small teams they work in, since all had come to work in these organisations as a result of similar other activities in the field, and could leave to pursue them elsewhere. "I would never be working in publishing unless it was going through a revolution." (developer, NPG)

Researchers and New Forms of Scholarly Communications

Our survey results suggest that, across disciplines, researchers regard subscription journals, online only or with a print version (since most print journals are also online), as the most important source of research information (91% and 89% rated as average or high importance) but open access journals are not far behind. We find a similar picture with respect to publication practices (Procter et al., 2010b). However, only 20% of respondents expected open access to become the predominant publishing model within the next 5 years.

More broadly, the survey results suggest that scholarly communications service innovations that are experiencing rapid uptake are generic, intuitive and easy to use, build incrementally upon existing practices, are available free or funded by advertising revenue, and offer near-zero adoption costs and clear advantages to users.

More specialised services, arising, for example, from the efforts of publishers and other knowledge intermediaries, that offer more scope for exploring novel forms of scholarly communication, have made more uneven progress. We now turn to our two case studies to examine why.

Case 1: From Nature Publishing Group (NPG) to Digital Science

This case study examines the services and innovations of a medium sized academic publishing company – Nature Publishing Group (NPG) specialising in Science and Medical academic publishing, a subsidiary of Macmillan Group. In recent years NPG has expanded its publishing business to include 40 Nature branded titles, such as the most recently launched, *Nature Chemistry*, and 40 other titles, either specialist journals, or those produced under contract to professional societies.

In the mid-2000s, NPG took the strategic decision to actively embrace innovation in scholarly publishing following a successful transition to web access to their publications sold via site licences. The small department that developed web publishing was enlarged and given company-wide responsibility for innovation in Internet services. The firm started to define itself explicitly as a 'Scientific Communications Company', recognising that the future of its business could not remain as a conventional publisher of printed, peer-reviewed journals. One respondent defined the motivation to invest and innovate: "Our future is now in the hands

of other people not ourselves and we need to take control of this". The aim was therefore not only to provide new services to Nature's scientific user base, but also act as an R&D lab to explore how to exploit the data in and generated around their key assets, scientific articles, including information produced by users and user activity, would drive users to publish and read more articles in NPG journals, and ultimately, sustain the NPG business, and inform other Macmillan businesses: "We're trying to do our job as a scientific communication facilitator." (publishing director, NPG)

The primary publishing platform, Nature.com, provides the gateway for journal users to access the group's publications. In the last 5 years, it has been augmented with a range of new services, including Connotea social bookmarking, Nature Blogs, Nature Network, audio and video content, and online databases. Experiments were conducted with open peer review, with facilities for commenting on articles, wiki versions of review articles, a preprint service and a Nature 'island' in Second Life virtual world. While many of these services remain in existence, a core part of the development team left NPG in 2011 to set up a sister company in the MacMillan group, Digital Science, free from the constraints of a business focused on publishing, to focus on a growing market for software to support science practice. Digital Science develops data management, metrics, and search services for research organisations and tools for individual scientists and supports start-up companies working in this domain such as Symplectic Elements and Altmetric⁵,

NPG has other new publishing activities that focus on the data sharing and repurposing of traditional content: databases and audio-visual. Many papers published in Nature journals also have their data published in data repositories that can be used alone and linked to other components of Nature.com from within the paper. Magazine and journal articles are now supplemented by audio and video material aimed at communicating both to scholars and the public, and promoting the Nature business. Global, regional and national sections have been produced in English, and local languages exploiting and serving the expansion of global scientific practice. There are services related to data and experimental procedures.

The NPG Business Model

NPG's main titles have professional editors with a background in science. The editorial staff manage peer review and editing processes, and maintain the quality of scholarly communication. Business staff have to make sure that these activities can be maintained commercially and to attempt to develop the business through turbulent times in scholarly publishing. The business 'vision' to become a 'science communication company' is quite bold: 'to ultimately increase the speed of scientific discovery by improving scientific communication'. However, as the business staff point out, the potential of the Internet is to facilitate a whole range of scholarly communications that are not mediated by journals but, nonetheless, offers business opportunities to an innovative publisher.

However, there are some tensions evident between the business and technology-led aspirations of the 'business' staff, and those of the editorial staff who provide the core product. A key issue is the quality of the final published products (and thus the Nature Brand): a Web 2.0 mode of interaction which may allow the comments of any reader or reviewer to be attached to an article on the Nature platform is potentially in conflict with the careful reviewing and editing processes, and risks undermining their professionalism and the Nature brand. A more prosaic reason for the editors is the time they would be expected to devote applying quality control to 'user-contributions' and providing the additional annotation necessary to link articles with other resources such as databases.

Public Library of Science (PLOS)

The Public Library of Science describes itself not as a publisher, but as a "nonprofit organization of scientists and physicians committed to making the world's scientific and medical literature a public resource" and, more prosaically, "a non-profit, a publisher and software house."⁶ It was founded in 2000 by leading biomedical scientists Harold Varmus,

⁵ Altmetric is an article level metrics company, based on the postgenomic track-back service, started by ex-NPG employee, which now provides article level metric services for PLoS <http://www.altmetric.com>

⁶ PLoS website: <http://www.plos.org/>

Patrick O Brown and Michael B. Eisen with the aim of promoting open access and innovation in ways to access and use scientific research. Their frustration with the publishing industry's failure to move to Open Access publishing led to the launch of two online, open access journals, PLoS Biology (2003) and PLoS Medicine (2004). Subsequently, four other subject-specific journals and a general science journal, PLoS One (2006), were launched, all of them publishing in the bio-medical field. These journals have become successful, attracting scholars to publish by offering fast turn-around times and providing a platform for them to comply easily with open access publishing requirements of funders.

One of the criticisms the founders had of existing journals – and Nature publications would certainly be in this category – is that the editors, given limited space in paper journals, and the need to maintain a journal brand and its impact factor, make a selection of papers based not only on scientific merit, but also on potential impact. The general-purpose journal PLoS One was founded specifically to break out of the constraints of print-based publications – developing a process of continuous publishing of peer-reviewed articles without editorial selection due to space constraints. Instead of only selecting articles likely to have 'high impact' to publish, PLoS selects certain articles post-publication to promote to the more general media. As the PLoS media manager says: "Scientists like that, they enjoy it, they can get lots of people to look at their work, there is nothing to stop them looking at it." (marketing editor, PLOS). PLoS One instead operates a more subtle form of filtering. The pay-to-publish model (although there are certain waivers) acts as a filter to publishing papers where authors are unable to pay the publishing fee.⁷

This large scale, continuous publishing process required the development and redevelopment of a model of filtering and distributing papers to editors and reviewers. These demands put the initial system, an open-source product not designed to be used in this manner, under considerable strain as the number of submissions and popularity of the journal grew month by month.

Since its launch amid the initial debate on Open Access publishing, PLoS has become less campaigning and more focused on publishing. Innovative activities have continued, led both by the board and staff. Innovation is done in a rather public experimental mode, developing the technical and organisational facilities to create a new service, and subsequently refining, evaluating and developing it with the community of users that it serves. At the same time, PLoS hopes that the innovations will attract scholars to publish in its journals. An example of another novel service, again driven by the founders and scholars, has been PLoS Currents, launched in 2009 in partnership with Google, using their now-defunct Knoll system, and since relaunched on an independent Wordpress platform. This is a 'pre-publication' online system aimed at providing a location for timely but so far un-reviewed work to be posted in a moderated forum. The first use was in response to the feared flu epidemic that year, and new use cases are being explored

PLoS is a much smaller organisation than NPG with small budgets and much smaller software/service development time, so the scale of their experimentations is much more limited. However, they have a high profile, and have focused on a small number of innovations notably PLoS One and Open Access that have been highly successful.

Early Experiments: Versions of Web 2.0 for Scholars

The case studies illustrate NPG and PLoS first investing in experimentation directly inspired by some of the successful (at that time) and emblematic Web 2.0 services, looking for ways to reproduce and tap into the practices of blogging and online media, including open commenting directly on articles, as if they were YouTube videos or blog posts (NPG and PLoS), 'wiki' versions of review articles (NPG) and building a social networking site for academics (NPG – Nature Network). Hanney (NPG) says of Connotea "I looked at Delicious, social book marking site ... and I said we should do something like this but tailor it for academic scientist." The idea was that mainstream Web 2.0 offerings were not quite adapted

⁷ For a lengthy online discussion of the PLOS One model, see the blog of the Society for Scholarly Publishing (SSP), June 21, 2010, PLoS ONE: Is a High Impact Factor a Blessing or a Curse? <http://scholarlykitchen.sspnet.org/2010/06/21/plosone-impact-factor-blessing-or-a-curse/> (Davis, 2010)

to scholarly needs, such as formal citation standards, but the idea of these services – the ability to 'share' or make public comments on articles – was somehow in the spirit of scholarship and consistent with new ideas of Open Science.

These developments were clearly seen as experiments that could only be developed successfully with close engagement with the scholarly 'community' and, in the spirit of Web 2.0 perpetual beta, NPG "set up a publishing department that has a remit not just to experiment with new things internally but to set up new user facing products and services that have a kind of experimental remit, an experimental approach." (publishing director, NPG) However, more was needed than just putting the service online. Both NPG and PLoS published articles and editorials, and set up blogs to enable a two-way dialogue with the scholarly and publishing communities, as part of a rather public design process. However, despite reaching use levels acceptable to keep them in existence, these experiments largely failed to reach a significant level of use, as was reflected in our survey findings. Despite this, out of these initial experiments came new ideas, new resources, and a more focused view of the role of publishers, and the potential and limits on how to develop and profit from innovation that both supported scientists and their own mission. This can be illustrated by exploring a selection of the services developed.

Social Bookmarking. NPG's Connotea bookmarking tool was envisaged as a research discovery tool, building on the citation database and user provided tags (Hammond et al., 2005). However, despite being integrated into the Nature.com platform, where many scholars read articles, it failed to become a frontline product. Less than 10% of our survey respondents reported using it frequently (i.e. at least once a week). It did not keep up with other products on the market recognised by NPG as better (e.g. Zotero). Users were seen not to be using it as a service to share links, but as a personal bibliographic system, compatible with the new practice of accessing and reading papers online. However, Connotea did provide NPG with a key data resource and continues to have several tens of thousands of users who provide NPG with a database of scholarly articles from across publishers, and their readers, which they can use to support other services.

Open Peer review, in-article comments and ratings. The early parallels between Web 2.0 practices of open commenting on media posts (blogs, music, video etc.), public dialogues between commenters and authors, and the practices of peer-review seemed clear to the developers at PLoS and NPG. Both organisations, as well as many other publishers⁸, instituted commenting on articles and, in the case of PLoS, article rating, NPG's web team were keen to build services around their key information assets – the articles – and comments seemed a way to explore the potential for post-publication peer review. However, the editors at NPG were not so enthusiastic, as they were worried about the quality of comments, and the workload necessary to edit them. This was compounded by resistance from readers: when commenting was made available, there was very little uptake, an outcome that is consistent with the results of our survey and interviews: only a small minority reported commenting on online journal articles (Procter et al., 2010a; 2010b). PLoS reported regular and small numbers of comments, but clearly the types of debates that happen on popular blog posts were not being reproduced. Ratings were virtually unused. As a PLoS respondent commented: "we came to an internal epiphany that basically you can't force people to comment on your site if they don't want to." Our survey, however, points to a deeper problem related to the value perceived by scholars as summarised by one interviewee: "Things like citation rates that come out of a formal process can be tracked (...), but reader comments and ratings would be so open to abuse it's hard to imagine that people would interpret it as valid of the paper's worth."

Use of Blogs. Both publishers started to use blogs, first as a way for the development teams to communicate with users, and later as a more strategic way to promote web-based discussion of science using links to their brand. NPG developed 'Nature Blogs', a 'White List' of approximately 1000 science bloggers who have been 'vetted', and whose blog posts are syndicated (and selectively edited) on the Nature site. Nature blogs also includes blogs written by members of NPG staff. PLoS staff regularly promoted PLoS and PLoS articles on

⁸ Some publishers appear to have more success than NPG or PLoS, for example, the Biomed Central and the BMJ, where extensive commenting is common, building on a long tradition of 'Letters to the Editor', and perhaps the awarding of a D.O.I reward and incentive to post.

blogs, even employing a professional science blogger to promote their ideas. In spite of the relative failure of 'Comments', NPG staff noted that many blog posts made extensive reference to journal articles, including in depth discussions, but these were not linked from the articles. The recruitment of the founder of the Postgenomic blog aggregator, who had already applied basic text analysis to blog posts to enable links to articles, enabled blog posts to be automatically linked with Nature published articles. This helps readers to find articles from blogs, and find blog posts from articles (trackback), a prototypical Web 2.0 mix of human and machine functionality exploiting what one respondent observed: "network effects don't just operate within one particular service, they operate across the whole web." (publishing director, NPG).

However, despite many popular blogs, especially in particular fields, it became clear that scholarly blogging would remain a rather fringe element of Web 2.0 and scholarship. A typical comment, representative of many in our survey, describes the professional scepticism towards scholarly blogs: "I think that getting involved in sort of all this web stuff is (...) a bit peripheral, not taken very seriously even blogs based on Nature [it's] time consuming and not very credible, interesting yes, but it's almost regarded as piece of entertainment (...) and potentially useful almost serendipitously." Nonetheless, the development of trackback from blogs would turn out to be a key element in the next stage of the strategy of both PLoS and NPG.

Social Network System. A final service, this time only developed by NPG, had to be, of course, a social network for scientists. At NPG this was part of a strategy to provide the Nature readership with a common identity across the various Nature services. It started from a local service that provided information on jobs, etc. to Nature staff. It was subsequently developed as part of the core Nature.com platform. Nature Network is in a nascent state⁹. There are many discussion groups and fora¹⁰, some quite lively. Nature Network is a core part of the development of NPG's scholarly communication strategy; they are keen to recruit many more users and to find ways to link it not only to internal services, but also to add value to external services. The fora on Nature Network are very much in the style of conventional bulletin boards, with implicit social rules of behaviour and a more or less active moderator but, nonetheless, illustrate how a publisher can successfully become a key mediator of new forms of online scholarly debate alongside traditional journal publishing. Perhaps one of the most interesting trends is the growth in use of the network by scholars in 'new' regions, such as the Middle East. However, again, a single publisher-centred system failed to really engage the scientific audience. Active users of Web 2.0 were using other services: a mechanism was needed to link Nature network with these other services. For example, one key group of users was the active bio-informatics community, who were heavy users of *Friendfeed*, an aggregator of RSS feeds from an individual's various social Web 2.0 tools. For a while this was integrated into the Nature Network.

Web 2.5: Towards Article Level Metrics and Linked Data

For both NPG and PLoS, making versions of Web 2.0 for scholars was an interesting experiment, but not necessarily a field where a publisher could either lead, or make an impact. Clearly, more focus was needed to find what elements of Web 2.0 were feasible for a publisher with software capabilities to develop, and would be valuable to all scholars, and not just those few plugged in to social media. Reflecting the findings of our survey, a PLoS respondent remarked: "10% [of scientists] care or know about Web 2.0 and only 1% of which would understand the conversation we're having [...] they're just regular academics going about their academic business and they're not really interested in all these wonderful bells and whistles. All they want is to be published in a journal with the highest impact factor and then they can retire happy". Over 60% of our sample used Google Scholar, way above the use rate of any other common tool, and this is a problem for a publisher trying to maintain a brand: "at the end of the day does anyone use it or do they just come in via Google and leave again and then come back to a different paper via Google?" (Marketing editor, PLoS)

⁹ NPG has not released details number of subscribers, or user activity but in 2012 claim 25000 registered users on the front page, which contrasts with over 350,000 subscribers to Nature News twitter feed.

¹⁰ In 2012 188 groups and 980 for were listed, but the majority appear inactive.

PLoS set out to systematically explore the possibilities of *article level metrics* (ALM), the first version of which was launched in September 2009¹¹. The aim of the strategy has been to continue the innovation process started in PLoS One, allowing articles to be judged on individual impact, rather than on the impact factor of the journal. The PLoS ALM programme publishes page views, download figures, citation rates from citation databases such as PubMed and Scopus, social bookmarking data, including data from Connotea, and links to blog aggregators (Nature Blogs, Bloglines and ResearchBlogging) and other online media to try and present a broader picture of impact¹². To develop the technology to do this was a considerable technical challenge, based on over 4 years of work. Continuing efforts are being made to find ways to generate this data: for example, in order to collect data on whether people were actually reading papers, rather than just scanning the document, figures were made clickable, generating a new indicator that could indicate depth of reading. Links to enabling bookmarking and linking from mainstream and scholarly social media sites are included on article pages to encourage readers to make the external link and thus generate new meta-data items. However, even prior to launch, the PLoS team recognised the cultural challenge to the scholarly community would be a much greater obstacle than technical elements. There are no established ways to interpret this data and, as was shown in our survey of researchers, many scholars disregard blogs and informal media as holding any importance. Nonetheless, nearly half (47%) of our survey expected peer review will be complemented by article level metrics of some sort in the future. To attempt to overcome scepticism, PLoS put in place a media and communications strategy to work with different communities of scholars to explain and get feedback on ALM and how it can be used. The data was made available for outsiders to analyse and comment on publically¹³. However, by December 2011, the 5th anniversary of PLoS One, the editorial admitted the slow progress of ALM: "we *plan* to improve our Article Level Metrics to a point where they will provide genuinely valuable context about individual articles and hopefully be more widely used and understood by decision makers such as tenure committees and funding bodies."¹⁴

NPG embraced ALM, not so clearly as PLoS, but clearly saw the market in advanced metrics for institutions. In setting up the new firm, Digital Science, this service could be developed cross-publisher, and services and products developed that would service institutional metric needs, such as the REF¹⁵ in the UK. However, in addition to this, NPG identified an opportunity to focus more on the data within articles, and use this as a resource to improve the value of the data, and build new services to support discovery and thus increase use of NPG journals: "How do we integrate the data that's associated with our papers?" (NPG). The key to this was seen as data mining: "What you really want to be doing is data mining based in order to improve the service, based on all the free information that you are getting from this. Doing the front end point without the backend part isn't really Web 2.0, it is just the appearance of Web 2.0 without Web 2.0." (developer, NPG)

Reader comments and ratings are not the only interesting ways of linking in and out of articles and, as has had been demonstrated, the world of social media metrics – and even conventional citation – has many limitations. Two key elements identified by NPG, and many others, were 1) the annotation of article texts to allow cross references to other articles and databases, thereby, facilitating easier knowledge discovery; 2) publishing and linking to data associated with the article, and to details of methods.

While NPG embraced the idea of making metadata available so that others could build services that would lead to discovery of NPG published papers, this cannot not be done if the metadata does not exist. The second element is closer to conventional publishing and NPG has developed services in this area. The first element has been the focus for the development of machine-based data mining technologies, but NPG recognises this is still in early days of development. Therefore, a Web 2.0 approach, mixing human and machine annotation was developed. The former is conducted by editors, who have the skills, but are reluctant to

¹¹ <http://article-level-metrics.plos.org/>

¹² For a discussion of scope and value of new forms of metrics see Priem & Hemminger (2010)

¹³ For example Jensen (2010), Adie (2009)

¹⁴ PLoS ONE: Five Years, Many Milestones, Dec 2011, everyONE blog

<http://blogs.plos.org/everyone/2011/12/20/plos-one-five-years-many-milestones>

¹⁵ Research Excellence Framework, a national review of research quality with results linked to funding.

embrace a new task; authors, who know their work, but are untrained; and readers who are the "least reliable." (developer, NPG) Machine annotation supports and complements the human, but is restricted by lack of common standards for describing entities such as genes (e.g. Shotton, 2012). Here, disciplinary divisions become important, and help explain why some disciplines seem to be developing some services more quickly than others: "in chemistry it is pretty easy to identify the mention of a chemical, and parse it, and there is a standard for numbering chemicals now. But in other domains, e.g. biology, names are common words, and it is hard even to identify when a gene is mentioned." (developer, NPG)

These insights and decisions by both organisations show a move from a rather shallow view of Web 2.0, to one that is much more focused on key resources and interests of a publisher trying to add value for readers. NPG, in particular, invested considerably in this, and championed the opening up of metadata and encouraging others so that resources could be integrated across publishers. While, in practice, annotation processes appear to belong in the publishing process, much of the data mining could be done elsewhere. However, as a subscription publisher, NPG appears to tie itself in knots to give access to all sorts of metadata, without actually making the data available.

Shaping Web 2.0: Scholarly Publishing as a Media Communication Business

We can situate these developments in Web 2.0 in the context of the changing scholarly publishing process. The development of ALM and linked data highlights two developing roles for the scholarly publisher. First, the publisher does not only do the behind the scenes technical work of managing, editing, reviewing and producing a journal, but is expected to actively promote the work it publishes, not only for the good of facilitating discovery of valuable scholarship to its readers and the general public, but to reinforce its brand and attractiveness for scholars who will then try to publish in the journals and – critically to this process – to raise the impact factor of a journal, its key currency. To do this, both PLoS and NPG have a 'full media strategy', selecting articles to promote in mainstream and social media: "At some level we're becoming like a broadcaster." (publishing director, NPG). Social media becomes part of general engagement with media in promoting the work of scholars, and thus the brand of the journals: "We embrace platforms from other people constantly – we use Twitter, Facebook, Wordpress." (marketing editor, PLoS)

Second, and this is one of the aims of ALM, the publishers are now trying to help authors, their employers, funders, etc. to understand the impact of their work, encapsulated in its most valued output, the article: "In an online world, the article is what it is all about, and it is the article that generates so many different impacts – the article will generate citations, blog posts, mainstream media coverage, social media bookmarking, downloads. There are so many new ways to see the reach of your research. "Who would not want to see their article on the front page of Time magazine?" (marketing editor, PLoS). Not only are individual scholars interested in who is using their research and how, but their institutions, funders, are also turning their attention to non-traditional 'use'. However, as PLoS identified, and consistent with the negative attitudes expressed in our survey, the social acceptance and valuing of these metrics is a much slower process than their technical development. Metrics are used to judge quality and impact, and the survival of a research lab or a research career is based on these judgements. Publishers are not just onlookers in these processes. Their business models stand or fall on metrics too. The introduction of new metrics helps them reinforce their own business and, unless they actually do the work of making these numbers available, there can be no debate about their value.

Innovation Practices

Now we have a sense of the types of Web 2.0 services and products being developed by these two organisations, we can explore in more depth elements of the processes of innovation that were used to create these products and services. The innovation process observed in our two case studies follows the Web 2.0 ethos of the 'perpetual beta': making early, simple versions available to a user community which experiments with and 'co-produces' new tools, services and content in a more or less continuous process (Morris, 2006). The perpetual beta style of development provides the opportunity for rapid feedback

on innovations before the investment is made to develop them fully (Procter et al., 2011). It facilitates the management of risk because it allows early evaluation and service change. The publishers made decisions to pursue some paths of development and are willing to sacrifice others where the evidence of uptake and returns on investment is lacking.

NPG initially followed inventions and innovations that have occurred in the broader Internet community, but is seen as a leader in the scientific publishing sector. It invested considerable resources in service development, focusing on what could be done, and the reaction of an enthusiastic community of users and informal testers, rather than working out a business model in advance. "If we're going to fail hopefully we can fail quickly and cheaply but try different things and see what works and see what will be useful and also see what we can make money out of and what we can't." (publishing director, NPG) "[in] their experiments you can't see with any of them what their business model is, how they're going to make money out of it. I think they're just in this mode of massive experimentation" (managing editor, PLoS on NPG). Like NPG, PLoS has followed innovations elsewhere in online publishing. With a small technical department, the PLoS developer admits that they have few resources to do more than modify the open source or licensed software systems they use. Like NPG, PLoS has attempted a number of innovations in information and communication practice that have required new tools to bring together diverse information sources, and has had to engage in a programme of outreach and dialogue with users and policy makers to promote its vision of shaking up traditional scholarly publishing,

On-going engagement with users is essential for driving forward innovation processes as well as adoption (Williams et al., 2005). The development of Web 2.0 tools and ideas by both NPG and PLoS was characterised by a diverse pattern of interaction with potential users through , conventional and new media platforms, where they attempted to justify their activities, and gain constructive feedback from readers and other stakeholders: "Innovation comes from having 2 way communication channels to allow them [the users] to shape what we do." (Marketing editor, PLoS) However, for PLoS and NPG, readers were not the only users to be engaged with: Directors, editors, authors, scholarly societies and outspoken scholars were part of a range of powerful stakeholders, including politicians shaping laws and regulations, and competitors with whom they needed to develop common standards and practices.

NPG promoted the company's vision and innovations at conferences, hosted and stimulated discussions on Nature Network, published articles and ran journal editorials on Web 2.0, experiments¹⁶ and the future of scholarly communications in general¹⁷. PLoS and NPG stimulated and encouraged debate in scholarly blogs. NPG have long experience in engaging with their specialist market and a good knowledge of the concerns of their users, with whom they keep up to date by engaging in public debate, informal communications and through everyday working relationships. As newcomers, PLoS were at a relative disadvantage and so employed someone from NPG to develop this capability for them.

To understand some of the dynamics of these development processes, we need to look more closely at these interactions. The development of the services featured in these case studies is often initially focused on the needs of groups of core, enthusiastic users: "We want to be in tune with the early adopter and working with them to develop services that hopefully the mainstream will eventually come along and find a use for. We don't want to be too far ahead cause that's as much a risk as being too far behind." (Publishing director, NPG) Often, these come from within a specific discipline where users are active in providing ideas, feedback and innovations in use. PLoS and NPG both highlight the importance of certain communities who are enthusiastic users and co-innovators of the Web 2.0 services they develop, notably in bio-informatics and chemistry.

Managing Uncertainty and Developing Future Prospects

The services highlighted in our two case studies are at a relatively early stage in their development, not so much in terms of their technical implementation, but in terms of the

¹⁶ Such as Hammond et al.'s (2005) review of NPG staff on social book marking, or the report on 'open peer review' experimentation (Greaves et al., 2006) and discussion in Editorials (Editorial Nature, 2006).

¹⁷ For example, a 'Nature focus' debate in 2004, Access to the literature the debate continues. <http://www.nature.com/nature/focus/accessdebate/> (accessed May, 2012)

development of stable user communities and patterns of usage. It will be clear from the preceding discussion that it is not always possible to predict the development trajectory of these innovations. Both publishers highlight the role of specific groups of users, noting that particular disciplines or sub disciplines have embraced what they are doing, while others reject. There are individual and cultural factors at place. There are also technical factors. Chemistry uses information objects amenable to early incorporation in linked data, and in social software tools, while biology and genetics do not. Different disciplines were more or less open to the ideas of 'sharing' data and community interaction: PLoS considers, for example, bioinformatics, to be very open, and molecular biology very closed: "Genetics and genomics are very used to sharing data. Anyone used to sharing very readily takes to this. When there is a disincentive to sharing, they will not take to it so readily." (developer, NPG)

Providers of innovative scholarly communications services need to develop an understanding of disciplinary practices and concerns, and may need to provide advice to potential users, for example, on the use of mechanisms for attribution or on data curation issues. Many of the innovative developments have yet to be embedded in the scholarly community and, while for 'technoenthusiasts' this may be seen as just a matter of time, institutional and cultural barriers, such as established publication models and issues of reputation, can be hurdles that have yet to be overcome (Harley et al., 2010).

Despite the potential of Web 2.0 services to disrupt existing practices of scholarly communication, the role of traditional publishers and of peer-reviewed journals remains strong. The development of Web 2.0 services by traditional publishers often serves to maintain this position in the face of potential challenges by new players such as PLoS. By creating new platforms, such as the network or the blogs, NPG is able to increase the status and visibility of its products and of those who contribute to them. However, as we noted earlier, publishers must be able to exercise editorial control. They can delegate this to users to a certain degree using a Web 2.0 'wisdom of the crowds' approach (Surowieck, 2004), it is not clear that 'crowds' are that enthusiastic to take part, or function effectively in the timeframe and scope of academic publishing, and without the careful intervention of publishers, which results in some type of control, such as white listing of bloggers and filtering of posts, or filtering of social bookmarks.

The NPG case study illustrates the tensions that established publishers may experience. On the one hand, NPG is developing a core platform that is their readers' main point of entry to their products and allows them to discover and discuss research, with many resources published under the Nature brand. On the other, the company realises that Nature is just a node in network of scholarly communication, and users are just as likely to find synergies between communication and information sources outside Nature as within, with the implication that everything has to be done to facilitate users in linking Nature to other sources and services. NPG is embracing *open data standards* in this respect to ensure that Nature.com remains a key point of passage for researchers.

The NPG case study also provides an illustration of how attempts to integrate Web 2.0 services in an organisation can put stresses on with established divisions of labour and working practices. Despite top-level management support, the introduction of novel practices based on Web 2.0 revealed differences of interest and practice within the organisation, reflected in a complex pattern of responses. An important influence here appeared to be relations with external users. Scholarly communities are taking to Web 2.0 in different ways and this is reflected in the attitudes of the NPG front-line editors, some of whom see no relevant user demand for journals to introduce features such as reader comments and editing. Although willing to experiment, there are strong concerns that novel practices such as reader comments and 'open' reviewing will undermine quality control. Some editorials asking for input to innovation received no feedback, and user comments facilities have been seen to be of very little use¹⁸. This is rather different from the experiences of the NPG Web 2.0 service development team, who receive a good deal of feedback from a quite narrow community of enthusiasts. Despite rather low initial uptake, the development of metrics of journal use and Web 2.0 services made available by moving online is starting to provide

¹⁸ For example, an editorial in a major Physics journal asking for feedback on Web 2.0 in science received no replies at all (unlike one in *Chemistry*).

important information for publishers and service developers. Developing a strategy that ensures support from within the organisation as well as effective and sustainable exploitation of the potential of Web 2.0 services is crucially important.

PLoS, on the other hand, started as a crusading organisation, wishing to shake up academic publishing, but soon had to face the reality of running a publishing business. They still attempt to innovate, but face considerable inertia from the scholarly community. The development of article level metrics is one example. Considerable technical development was needed to bring together a range of metrics that might measure the impact of an individual article. This was a necessary step to promote their goal of reducing the importance of a journal's brand on the evaluation of the impact of a paper. However, launching ALM was only the first stage in stimulating a conversation with the scholarly community over the usefulness of ALM, which could only be established by actually having it used. Without other publishers doing the same, however, the success of the venture must be very much in question.

Returning to the idea of publishers as innovation intermediaries (Stewart and Hyysalo, 2008; Howells, 2006), it is clear from our case studies that, though NPG and PLoS developed little original technology, they were able to play an important role in stimulating experimentation and debate at the heart of scholarly communications, and in the everyday practices of early users. Their rapid integration of service innovations with existing platforms facilitated joint experiments between users, developers, editors and other stakeholders. As high profile organisations, they were able to bring these to the attention of stakeholders, and to act as legitimate actors and as brokers of ideas. In this process, they were up against some powerful, alternative voices and embedded institutional constraints.

Conclusions

Our findings shed light on the attempts of two journal publishers to take on board new forms of scholarly communications, and find ways to appropriate Web 2.0 technologies and ideas that not only satisfy their audiences, but fit the practicalities of running peer-reviewed journals and make commercial sense. They illustrate the tensions that publishers can experience in their efforts to innovate service offerings and develop sustainable business models. Web 2.0 technologies can not only improve information management, discovery and sharing, but also provide an important source of knowledge for service providers. However, while some may use this for advertising or other revenue generation, it is not yet clear whether or how scholarly publishers can take advantage.

Our study suggests that, despite the focus often given to Web 2.0's 'bottom-up', user-led dynamics, the capacity of established players in the scholarly communications area to harness technical innovations such as Web 2.0 looks certain to have a major bearing on progress towards new forms of scholarly communications. The scholarly publishing industry's innovative capacity varies widely among its members, and related strategy and consequent capability development rather than size and resources. An experimental approach – developing many prototype services and seeing what works – is generally cheap, quick and easy to learn from: it can be done by the smallest scholarly society and by major corporations: the former benefitting from institutional flexibility and the latter from deeper pockets. For experimentation to have an impact, however, it needs to be delivered to users in ways that mesh with their everyday practices. It is also clear that to move beyond experiments to services that really take advantage of Web 2.0 and social software can offer, considerably more investment is required.

We have seen how NPG and PLoS have tried to play the role of innovation intermediaries: they are able to perform a brokering role by controlling some key assets, and having high visibility and presence. However, in reality, they have only partial control, so it is difficult for them to act as a gatekeeper. In making new services available they might be cast in the role of facilitators of experimentation by the scientific and publishing community, and configurers of technologies, and the form of published scientific outputs. However, they find that just providing facilities does not change users' practices over night. When initial experiments in commenting and rating failed to take off, NPG and PLoS turned to a model of scholarly publishing service centred on finding and linking out to other sources. This is geared to providing scholars with tools to begin to understand what happens to their own work when it

is published, to track how articles are being 'consumed' and by whom, though it is far from clear how the metrics will be adopted and used. To develop this model further publishers will need to work together and with other stakeholders to promote their ideas and develop open data *standards*.

Online fora, editorial and reviewing systems provide publishers with a platform to present innovations to their users, who, in turn, get to try out novel features. However, we have seen how publishers may face differences of view from within their own organisations, and apathy and resistance from users, as well as pressure from research funders and critics to open their practices and data. Publishers such as PLoS and NPG may be able to design suites of services that build their brand and utility for users, making it easier for them to discover and reference articles and data within their publications. However, the benefits they might reap from this are constrained by being just one node in a heterogeneous network of scholarly communication and users and the increased ease with which users may follow links to external sources. The challenge for publishers as they embrace new forms of scholarly communications is to ensure that they remain a key point of passage in the scholarly communications cycle when scholars may be just as likely to find synergies between communication and information sources beyond their own service offerings as within them.

More generally, we draw attention to the emergent character of the new knowledge infrastructures of scientific research. We note the uneven dynamism that surrounds the generation of new tools and services, their adaptation to the needs of particular groups of researchers, the responses of the research community and the wider research and education institutions – and the widely dispersed processes of social learning through a perpetual beta approach involving trial and error experimentation with innovative tools and practices. This study has broadened our view of the range of pertinent actors and drawn attention to various innovation intermediaries and, in particular, publishers and other players (e.g. conference organisers, scholarly organisations) that constitute the infrastructures of scholarly communications that have hitherto been little addressed. Another kind of intermediation may be important in social learning (Sørensen, 1996) in capturing local innovation experiences and exploring how they may be applied in other settings. Some publishers are in the vanguard of this process. We hope that this study may also play a role in mapping out pathways for the emergence of effective future systems of scholarly communication, geared more closely to the exigencies of research communities.

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Competing interests

The views expressed in this article are the author's and do not necessarily reflect those of the European Commission. The authors declare that they have no competing interests